Battelle
Columbus Division

Probable Levels of R&D Expenditures in 1984

Forecast and Analysis

This report, from the Columbus Division of Battelle Memorial Institute, is based upon a continuing study of U.S. expenditures for research and development. It was prepared in the Applied and Technical Economics Department by Drs. Jules J. Duga and W. Halder Fisher. Parts of the data presented here were derived from such sources as the National Science Foundation, the McGraw-Hill surveys, and others.

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PROBABLE LEVELS OF R&D EXPENDITURES IN 1984

SUMMARY OF FINDINGS

1. Battelle forecasts that the total U.S. expenditures for R&D will be $94.2 billion during calendar year 1984. This is an increase of 8.9 percent over the $86.5 billion that the National Science Foundation (NSF) estimates actually will be spent in 1983.

2. Costs of performing R&D are expected to rise 5.0 percent from 1983 to a 1984 index level of 223.85 (1972 = 100 percent), absorbing a considerable amount of the increased funding. However, this implies a *real* increase in expenditures of approximately 3.7 percent, reaching a new peak in total real funding of R&D (Figure 3).

3. Federal government funding in 1984 is expected to be about $42.7 billion (45.3 percent of total), an increase of $3.1 billion (7.8 percent) from 1983. Performance of R&D by the Federal government will represent $10.3 billion (10.9 percent), an increase of $0.5 billion (5.3 percent) over 1983 estimates.

4. Industrial funding in 1984 is expected to be approximately $48.8 billion (51.2 percent of total) representing an increase of $4.55 billion (10.3 percent) over that of 1983. Performance of R&D by industry is expected to rise to $70.8 billion (75.2 percent of total), an increase of $6.6 billion (10.3 percent) over 1983.

5. Estimates of Federal versus industry support for the R&D performed by each of several broad industrial sectors are included in the 1984 forecast. Drawing upon historic trends, the anticipated total performance by the industrial sector has been distributed: first, within each of 17 major industrial groups, and then according to whether that performance is supported by Federal or industrial funds. These estimates are shown in Table 4.

6. In 1984, the Federal government is expected to support almost three-fourths of the aerospace industry's R&D activity, two-fifths of electrical machinery communications and more than one-fourth of rubber products. All other broad manufacturing industry classes are expected to be supported primarily by industry funds. These ratios range from 84 percent for professional and scientific instruments up to 100 percent for the textile, paper, and the food and beverage industries. Overall, 32.2 percent of industrial R&D will be Federally funded with the remainder (67.8 percent) funded by industry.

7. Academic and other nonprofit institutions taken together are expected to fund $2.70 billion of R&D in 1984 (2.86 percent of total) and to perform $13.1 billion (13.9 percent). Both of these figures represent small decreases in the percentage of support and performance over the 1983 NSF estimates. These figures also include the Federal support to Federally Funded Research and Development Centers which are managed by individual universities or consortia.

8. Within the nonprofit category, colleges and universities are expected to account for 63.3 percent of the 1984 funding and 80.1 percent of the R&D performance, an insignificant difference from the 1983 NSF estimates.

9. The costs of R&D performance have risen steadily in all four categories (Federal, industrial, colleges and universities, and other nonprofits), with the rate of increase being driven primarily by overall inflation, but also by the so-called "sophistication" factor.

10. The trends in real R&D effort (see Figure 3) are continuing the upward movement established over much of the past decade. Since 1973, real R&D effort has increased at a 10-year average rate of 3.71 percent, and the projections for 1984 suggest that the 11-year average rate will continue at this same rate. Battelle estimates that during the decade of the 1980s, real R&D activity will increase at an average annual rate of approximately 3 percent.

11. Significant factors that appear to be influencing trends in the support and performance of R&D include:

    (a) Federal emphasis on defense and space programs will have a continued influence on total R&D support and the principal industrial performers; these emphases will be felt primarily in the aerospace and electronics and communications industries.

    (b) Energy-related R&D programs will continue to experience decreased Federal support, with the exception of programs characterized as having very high risk or long-term payoff; even within these categories, there is little evidence that energy is perceived as a national problem requiring Federal R&D support.

(c) Increased industrial support of R&D may be reflecting the impact of the tax credits instituted two years ago.

(d) University self-funding of R&D is expected to begin to show real increases, partially as a result of expanded industrial "directed programmatic endowment" support of basic and applied research.

(e) Although no details are presently available, it is expected that major new funding patterns may emerge as a result of increased activity in multiple-supported industrial research programs.

12. As a special feature, the report provides a preliminary forecast of R&D funding levels in 1985. The preliminary data show the total U.S. expenditure for R&D in 1985 to be $101.2 billion.

ANALYSIS AND FORECAST

Since research and development (R&D)* is Battelle's prime concern, it has an intense and abiding interest both in forecasting R&D expenditures and in assessing the cumulative results of R&D activities— technological, economic, and social. Accordingly, the Columbus Division has carried on a continuing inquiry into the forces affecting R&D activities and into their sources of support. Among the tangible outputs of this research have been a series of annual analyses and forecasts of R&D expenditures, of which the present report is the latest.

The content of this analysis and forecast of the R&D situation has evolved over the years in an attempt to supply information that Battelle considers useful to the R&D community, but was not being supplied by two well-known and respected series of reports: the National Science Foundation's *National Patterns of Science and Technology Resources* and the McGraw-Hill *Annual Survey of Business Plans for R&D*.

Earlier, the NSF *Patterns* were published during the first half of each year (usually in April) and included a forecast of that same full year's R&D expenditures, by source of funds and by performer. However, since the change to the fiscal year which now begins in October, *Patterns* contains both the preliminary data for the closing fiscal year and estimates for the two preceding years.** The McGraw-Hill surveys (usually published at about the same time as *Patterns*) make forecasts— the 1983 Survey (published in May) made forecasts for 1983 and 1986— but are confined to the performance of the industrial sector and do not separate Federal from industrial funding. The Battelle report, usually published in December, has been intended to fill in a timely manner the niche that involves especially the coming year (in this case, 1984) and industrially funded R&D. Other relevant information, gleaned from many sources, also has been included.

Beginning with the 1980 forecast, we also have included a forecast of industrial R&D expenditures by broad industry class, along with the estimated distribution of those funds between industrial and Federal sources. This added feature provides the background necessary to an understanding of the way in which Federal policy can affect industrial innovation, can spur industrial support of its own R&D efforts, and can enhance the longer-term international competitiveness of U.S. industry. Although related aspects of productivity, training and manpower needs, tax incentives, balance of payments, and other concerns are not predictable, we anticipate that continued analysis of this subject will help identify both the promises and the problems associated with industrial responses to future opportunities.

For the first time in the Battelle series, estimates are presented which cover a *two*-year forecast, to 1985.

Historical Trends in R&D Funding and Performance

Although the NSF data series goes back to 1953, we begin our analysis with 1960. Even that year represents ancient history so far as the forces currently affecting R&D are concerned. The NSF data from 1960 through 1983 are shown in Table 1.

In 1960, NSF surveys indicated that approximately 64.6 percent of all R&D supportive funds were provided by the Federal government; 33.4 percent were provided by industry; and 1 percent each came from the academic community and from other nonprofit organizations.

Between then and 1983, Federal funding rose to 66.5 percent in 1964, and has slowly declined to 45.8 percent.*** Over that same time period, industrial funding declined to 31.2 percent in 1964 and has risen to 51.2 percent in 1983,

* The National Science Foundation's definitions of R&D are given in the Technical Appendix to this report.

** For the last two years, the *Patterns* report has been issued later in the year, and, because of "rolling delays", no 1983 report is expected. However, some of the preliminary data that would have appeared in the 1983 *Patterns* have been made available for inclusion in this report. It is expected that the 1984 *Patterns* will be published at or near its usual time of the year. The authors gratefully acknowledge the assistance of NSF staff in providing this information.

*** Note that NSF data for 1981-1983 are "preliminary" or "estimated". However, comparisons among the series of *Patterns* reports reveals that adjustments are made on earlier years' figures, with such adjustments carrying back as far as 1977.

with a small increase to 51.8% expected in 1984. The two nonprofit sectors have risen gradually, colleges and universities to 2.2 percent and other nonprofit to almost 1.6 percent, although these percentages have declined over the past four years.

Generally, recent trends suggest a continued increase in industry funding as a percent of total funding, with a corresponding decline in Federal sector contributions. The extent to which this behavior will continue will rest largely upon the posture assumed by the Administration, the industrial response to Federal initiatives, and the general state of the economy.

Although the Federal government had been the major *source* of R&D funds from 1953 to 1979, its dominance has been eroded since 1980. Industry is by far the major *performer* of R&D. Federal performance of R&D rose from 12.7 percent in 1960 to 16.1 percent in 1972 and has been fluctuating since that year, albeit with a generally decreasing percentage. Industrial performance reached a high point of 79 percent in 1957, and drifted steadily downward to a low of 68.6 percent in the early 1970's; more recent trends suggest a slow increase in the proportion of industrial performance, rising to over 74 percent. While the academic community's performance varied between 6 and 8 percent prior to 1960, there has been a slow but steady increase in the percentage of R&D performed in this sector, with recent proportions around 12 percent. Over the past few years (since 1980) this sector's share has been declining slightly. For most of the 1960-80 period, other nonprofits, including Battelle, have grown from 2 to about 3 percent of the total, again with recent declines in that share.

It should be noted that Federal funding supports

TABLE 1. SOURCES OF R&D FUNDS AND PERFORMERS OF R&D, UNITED STATES, CALENDAR YEARS 1960-83

(Millions of Current Dollars)

		Sources of Funds				Performance[a]			
Year	Total R&D	Federal Gov't	Industry	Colleges and Universities[b]	Other Nonprofit[c]	Federal Gov't	Industry	Colleges and Universities	Other Nonprofit[c]
1960	13,523	8,738	4,516	149	120	1,726	10,509	1,006	282
1961	14,316	9,250	4,757	165	144	1,874	10,908	1,173	361
1962	15,394	9,911	5,123	185	175	2,098	11,464	1,374	458
1963	17,059	11,204	5,456	207	192	2,279	12,630	1,611	539
1964	18,854	12,537	5,887	235	195	2,838	13,512	1,904	600
1965	20,044	13,012	6,548	267	217	3,093	14,185	2,103	663
1966	21,846	13,968	7,328	304	246	3,220	15,548	2,345	733
1967	23,146	14,395	8,142	345	264	3,396	16,385	2,594	771
1968	24,605	14,928	9,005	390	282	3,494	17,429	2,868	814
1969	25,631	14,895	10,010	420	306	3,503	18,308	2,950	870
1970	26,134	14,892	10,444	461	337	4,079	18,067	3,072	916
1971	26,676	14,964	10,822	529	361	4,228	18,320	3,216	912
1972	28,477	15,808	11,710	574	385	4,590	19,552	3,383	952
1973	30,718	16,399	13,293	613	413	4,762	21,249	3,701	1,006
1974	32,864	16,850	14,878	677	459	4,911	22,887	3,888	1,178
1975	35,213	18,109	15,820	749	535	5,354	24,187	4,396	1,276
1976	39,016	19,914	17,694	808	600	5,769	26,997	4,874	1,376
1977	42,829	21,642	19,629	887	671	6,060	29,825	5,449	1,495
1978	48,184	23,933	22,450	1,035	766	6,870	33,304	6,338	1,672
1979	54,972	26,860	26,081	1,194	837	7,463	38,226	7,289	1,994
1980	62,734	29,716	30,771	1,314	933	7,763	44,505	8,285	2,175
1981[d]	72,118	33,752	35,897	1,512	957	8,729	51,830	9,269	2,290
1982[e]	79,000	36,610	39,955	1,540	895	9,250	57,550	9,550	2,350
1983[e]	86,500	39,625	44,285	1,615	975	9,750	64,250	10,000	2,500

Source: National Science Foundation, Science Resource Studies *Highlights*, NSF 83-316, July 22, 1983.

(a) The R&D performance of Associated Federally Funded Research & Development Centers (some administered by industry, some by colleges and universities, and some by other nonprofit organizations) has been combined with that of the administering institutions.

(b) As sources of funds, these include state and local government funding.

(c) All other nonprofit institutions.

(d) Preliminary figures provided by NSF.

(e) Estimated by NSF.

research performed by all four sectors. Currently, almost one-fourth goes to support intramural R&D; over half goes to industry; approximately one-fifth goes to colleges and universities; and the rest, slightly more than 4 percent, goes to other nonprofits. Industry absorbs almost all of its own funds, either intramurally or by contract with other industrial performers; its contracts and grants to colleges and universities slightly exceed those to other nonprofit institutions. Other nonprofits finance both themselves and the academic institutions about equally, while colleges and universities absorb all the funds that they originate.

In Table 1 we summarize the latest NSF time series on the sources of R&D funding and on the volumes of R&D performance. During the interval since 1960 total R&D dollars (not adjusted for inflation) have more than sextupled. Federal funding has multiplied by more than 4.5 and Federal performance has increased by a factor of 5.7. In terms of constant dollars, total R&D expenditures have increased by 77 percent during 1960-83, and Federal performance has increased by 34 percent (see Table 6). Using the same deflator for Federal funding that we used for total expenditures, real Federal funding increased by about 26 percent.

Also noteworthy is the high ratio of academic performance to academic funding. In the later years of this period, colleges and universities have provided about one-sixth of the total support of their own R&D activity, with the remainder coming primarily from the Federal government.

Beginning in 1968, there was a distinct change in the rate of growth in R&D, manifested by a leveling in current-dollar Federal funding. This phase of the recent past seems to have ended with 1971, when current-dollar expenditures resumed an accelerating growth trend more nearly like that before 1968. More recent trends suggest a continued growth of total real R&D support.

Continued Transition

As was pointed out in the last two years' forecasts and analyses, U.S. R&D is in a period of significant transition. The forces governing this transition, insofar as the Reagan Administration is concerned, were stated in these terms: "Perhaps the overriding factors which characterize this Administration's posture are: (1) the major commitment toward expansion of defense capabilities; (2) a strong support of the private sector -- both through taking positive actions and through relaxing negative requirements; (3) the belief that many areas of governance should be left to State and Local governments; and (4) an attempt to balance Federal budgets through the reduction or elimination of a broad range of programs."*

Furthermore, Administration policy has strongly favored the reduction of support in those areas (especially energy) which (1) are no longer considered to represent national crises, or (2) are thought of as being more appropriate for the private sector. To these forces also should be added two factors that have become even more crucial with the passage of time than the policy directives of the Administration: namely, worldwide economic depression and growing technological challenges from other countries.

Of particular concern at this time are the continuing competition from other countries and the diplomatic and military tensions that exist throughout the world. Furthermore, mammoth budgetary deficits continue to plague the Federal government. While there are philosophical and ideological postures that would normally be expected to force deficit reductions, there also are constraints to the lowering of expenditures and the raising of taxes. Neither of these approaches is expected in an election year, and neither would necessarily benefit the research community and the ultimate economic and technological expansion interests which that community serves.

Forecast for 1984

During calendar year 1984, Battelle expects the total current dollar volume of R&D activity to be higher than the level estimated by NSF to be achieved in 1983 (though not as great as expected by NSF for 1984). A comparison of Battelle's 1984 forecast with the last available NSF estimates for 1983 is shown in Table 2. The 1984 forecast is shown in its historical setting in Figure 1.

Referring to Table 2, we estimate total 1984 R&D volume to be $94.2 billion, an 8.9 percent increase over the NSF estimates for 1983. It is expected that much of this increase will be absorbed by continued inflation (which we estimate to be 5.0 percent from 1983 to 1984 for R&D).

In connection with this forecast, there are three particular *caveats* that must be noted. First, the actual current-dollar total that will be realized in 1984 is very dependent upon inflation. The projection given here reflects, in part, the lowest adjusted R&D inflation rate in recent years.

Second, these projections cannot take into account the changes yet to be made as the Congress and the Administra-

*Page 4 of the 1983 *Forecast and Analysis*.

tion finally compromise on the Federal budget for FY 1984. As of this writing, although the fiscal year has already begun, almost nothing is in final appropriation. Since 1984 is a major election year for both Congress and the Administration, final appropriations and authorizations may be modified in response to political considerations. Actions taken on the budget will serve as points of debate in the upcoming campaign.

Third, industrial support of R&D will be dependent upon three factors: (1) business conditions over the past two years; (2) the full impact of earlier tax laws; and (3) the general state of business optimism regarding the potential economic growth over the next half-decade. More will be said of these factors in a later section of this forecast.

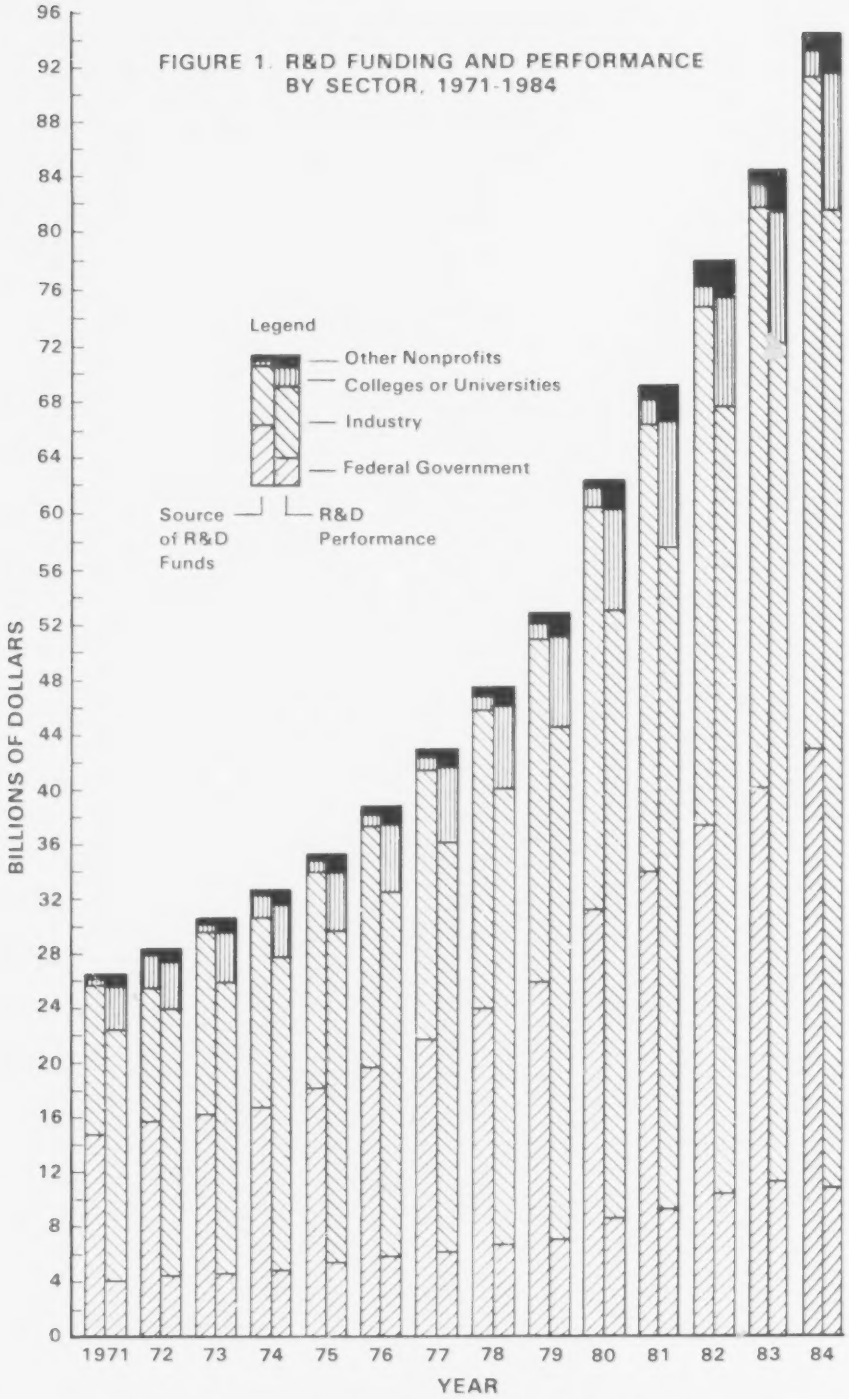
In using Table 2, the reader should keep clearly in mind all the distinctions made by the table headings. For instance, in the *column* headed "Industry", we see that the total amount of R&D expected to be performed by industry in 1984 will be $70,852 million. Of this, $22,801 million will be funded by Federal agencies, and $48,051 million by industry. On the other hand, the *row* headed "Industry" indicates that industrial sources of funds are expected to support about $48,838 million of R&D. Of this, $48,051 million will be performed by industry, $396 million by colleges and universities, and $391 million by other nonprofit organizations.

Continued inflation is expected to characterize 1984, although the rate, as experienced in R&D, appears to be declining. In addition, there are many intangibles — partly the increased feeling on the part of both Federal and industrial decision-makers that R&D is vital to long-term economic health — that favor continued increases in support. The NSF estimated that current dollar R&D activity rose by 9.5 percent from 1982 to 1983; we project a smaller increase, 8.9 percent, from 1983 to 1984. As will be shown

TABLE 2. ESTIMATED R&D EXPENDITURES BY SOURCE OF FUNDS AND BY PERFORMERS, U.S. CALENDAR YEARS 1983 AND 1984

(Millions of Current Dollars)

Source of Funds		Performer: Federal Government	Performer: Industry	Performer: Colleges and Universities	Performer: Other Nonprofit	Source Totals: Dollars	Source Totals: Percent of All Funds
1983 NSF Estimates							
Federal Government		9,750	20,675	7,550	1,650	39,625	45.81
Industry		—	43,575	360	350	44,285	51.20
Colleges & Universities		—	—	1,615	—	1,615	1.87
Other Nonprofit		—	—	475	500	975	1.13
Performer	Dollars	9,750	64,250	10,000	2,500	86,500	
Totals	Percent	11.27	74.28	11.56	2.89		100.00
1984 Battelle Forecast							
Federal Government		10,270	22,801	7,915	1,715	42,701	45.31
Industry		—	48,051	396	391	48,838	51.83
Colleges & Universities		—	—	1,706	—	1,706	1.81
Other Nonprofit		—	—	491	500	991	1.05
Performer	Dollars	10,270	70,852	10,507	2,605	94,234	
Totals	Percent	10.90	75.19	11.15	2.76		100.00
Percentage Increases Over 1983 Estimates							
Federal Government		5.33	10.28	4.83	3.94	7.76	
Industry		—	10.27	10.00	11.71	10.28	
Colleges & Universities		—	—	5.63	—	5.63	
Other Nonprofit		—	—	3.37	0.00	1.64	
Performer Totals		5.33	10.28	5.07	4.20	8.94	



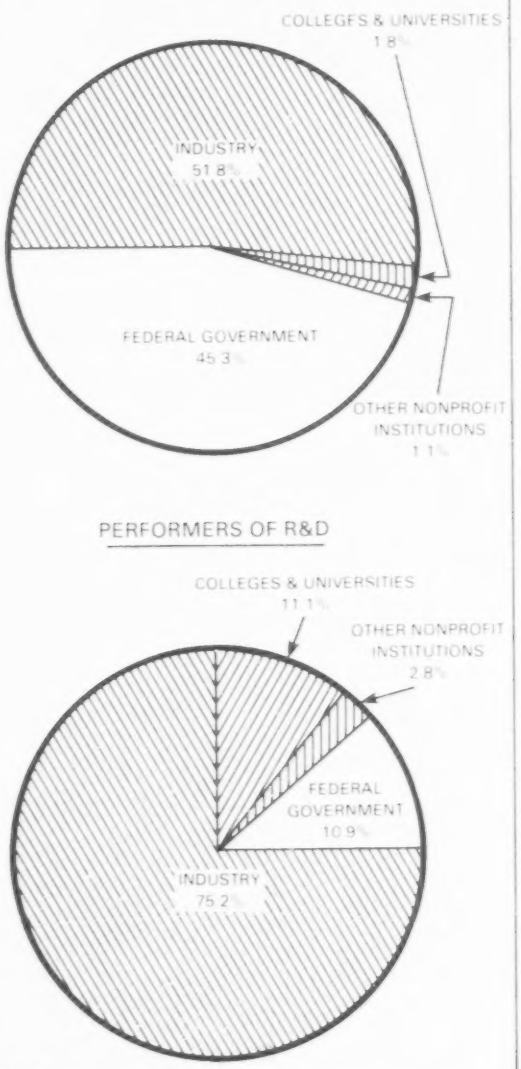
See Tables 1 and 2. 1971-1983 estimates by NSF; 1984 projected by Battelle's Columbus Division.

in connection with the Cost of R&D Index, not all of this increase is expected to be absorbed by inflation.

With respect to the *composition* of R&D activity, the expected pattern continues to be one of year-to-year stability or very slow change – with defense, science- and technology-based problems, considerations of economic development, and foreign competition still providing the major impetus for change. The proportionate composition of both funding and performance will change very little. The Federal government will account for 45.3 percent of the total funding, as against 51.8 percent for industry. Industry will account for approximately three-fourths of total performance. These two distributions for 1984 are summarized in Figure 2.

FIGURE 2. R&D EXPENDITURES IN THE U.S., CALENDAR YEAR 1984

The total forecast by Battelle's Columbus Division is $94.2 billion. Distribution shown here is by source and performance.



Source: Battelle's Columbus Division

The Role of Federal Agencies

Since Federal funding was historically the major source of R&D support (although it has been increasingly outdistanced by industrial support since 1980), the forces likely to affect Federal R&D budgets in Fiscal Years 1984 and 1985 are important in the present forecast. The Budget for Fiscal Year 1984, which began on October 1, 1983, is almost entirely a product of the Reagan Administration. It exhibits major departures from prior trends and sets the stage for what may be significant changes in subsequent years.

The significant increases in defense spending – in terms of both hardware and research – will be continued by the Administration's commitment to new weapons systems. Furthermore, Budget plans through 1988 – while certainly subject to modification in the future – set a direction which suggests continued emphasis in this area. Only a major change resulting from the 1984 elections would have an influence on current trends, although the extent of that influence would most likely not be felt until about 1986.

Battelle projects $42.7 billion as the most likely level of Federal funding in calendar year 1984. This figure is based upon: (a) recent trends in Federal budgeting, as reflected in NSF data series on R&D funding; (b) the relationship between Federal funding and Federal obligations; (c) the fact that three calendar quarters' funding will be determined by the FY 1984 appropriation; and (d) a strengthening of selected mission agency activities. This estimate is consistent with budget figures, although slightly lower than that suggested by the American Association for the Advancement of Science.*

The R&D-Minded Agencies

The big-money agencies in terms of total 1984 R&D funding will include the Department of Defense (DOD),

*See, for example, *AAAS Report VIII: Research & Development, FY 1984*, American Association for the Advancement of Science, Washington, D.C., 1983.

the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the Department of Health and Human Services (HHS). Among the smaller agencies, the important suppliers of funds for extramural R&D are the NSF, the Department of Agriculture (DOA), the Environmental Protection Agency (EPA), the Department of the Interior (DOI), the Department of Commerce (DOC), and the Department of Transportation (DOT). Estimated shares for the conduct of R&D in the early proposed budgets for FY 1984 and comparative estimates of the FY 1983 plans are:

	1983 Estimated Authority	1984 Planned Authority
DOD	58.9 percent	64.5 percent
NASA	8.2	7.0
DOE	11.7	9.9
HHS	11.0	9.5
NSF	2.7	2.7
DOA	2.2	1.8
DOT	0.9	1.1
DOC	0.8	0.5
DOI	0.9	0.7
EPA	0.6	0.4

It is obvious from this listing that DOD continues to dominate the Federal scene, accounting single-handedly for almost two-thirds of the R&D budget. The Big Four (DOD, NASA, DOE, and HHS) account for 90.8 percent of anticipated Federal R&D expenditures. The next six largest R&D-supporting agencies account for only 7.3 percent, and all others combined account for less than 2 percent.

These percentage distributions reflect the continuing impacts of the Reagan Administration. The 1984 structure is still subject to modification by the Congress, although no significant changes are expected.

Functional Categories

Although some of the important R&D agencies are primarily devoted to a single function, many are multifunctional. The NSF utilizes a master list of 17 functional categories, of which the most important have the following shares of estimated 1983 and 1984 budget authorities:

	1983	1984
National defense	64.8 percent	70.0 percent
Space research & technology	4.9	4.2
Health	11.0	9.5
Energy	6.7	5.1
General science	3.9	3.8
Environment & natural resources	2.4	1.7
Transportation	2.3	2.4
Agriculture	1.9	1.6

The remaining functional fields, each receiving less than .5 percent of the total R&D budget, are: education, training, employment and social services; community and regional development; international affairs; veterans' benefits and services; commerce and housing credit; income security; administration of justice; and general government. Altogether, these smaller fields account for only 1.7 percent of the total.

As had been expected in earlier forecasts, the major increase in R&D expenditures will be confined to that in support of national defense. There will be some substantial increases in other areas, and slight increases in many agencies or functional areas (such as an anticipated 45 percent increase in the R&D budget for the Department of Transportation). However, as a fraction of *total* Federal R&D, almost all agencies and functional areas – except for defense – will show relative declines.

The significant increase in defense spending primarily is directed toward the acquisition of major weapons systems and the R&D that will be necessary to support them. The emphasis on space-related R&D also is expected to continue, although probably at a lower rate of effort. The continued success of the Space Shuttle program and the potential use of the shuttle as an instrument for more economical insertion and repair of satellites is seen as justifying continued support of the program for both civilian and defense purposes. A redefinition of NASA expenditure classifications and the transfer of much of the Space Shuttle support from "research and development" to "operational" programs will introduce some anomalies in the R&D accounting.*

*For a more detailed analysis of all Federal agency programs and their elements, see "R&D in the FY 1984 Budget: A Preliminary Analysis", AAAS, Washington, D.C. (March, 1983).

From 1969-70 to 1973-74, year-to-year changes in R&D budgets favored civilian programs over defense-space. Beginning with 1974-75, emphasis has tended to shift back toward defense and space, especially the former. Throughout the 1970's, the funding of energy-related R&D generally grew by larger increments than that of space or of most other civilian programs. It is generally expected that Federally-supported energy-related research and demonstration programs will decline, except for that portion which is in support of direct national defense interests. Some existing DOE programs may be transferred to other agencies, and those which involve short-term and/or low-risk R&D probably will have to be financed by private industry.

Factors Affecting Future Federal Support

There appears to be a continuing effort on the part of the Federal government to increase its funding of R&D, in terms of both support to basic national needs and the broadening of the technological base on which future growth is predicated. National security, reflected in the DOD budget, is seen as a principal driving force in furthering R&D spending. Economic growth, founded upon both basic and applied research, is expected to remain as an objective which requires direct and indirect Federal support, although greater emphasis will be directed toward the latter.

The continuing emphasis on energy, and the associated problems of balance of payments and insecure resources, will result in increased efforts on the research, development, demonstration, evaluation, and diffusion of new energy technologies. These efforts will be directed toward both the supply and the consumption sides of the energy equation, but with decreasing Federal involvement.

In addition, it is anticipated that R&D moneys will continue to support the biological science areas. However, less emphasis will be placed on "soft" science areas, except those environmental, ecological, and socioeconomic impact investigations presently mandated by law.

There is a continuing mood on the Federal scene which is manifest in the government's actions to enhance economic strength through research, development, and application involving the private sector (see the following sections on the role of industry). The posture of the government is not so much toward assisting industry directly, as toward reducing the impediments and risks associated with R&D. Favorable tax incentives and a relaxation of regulations that inhibit cooperative research programs are seen as a means to reduce both burden and risk.

Previous reports in this series addressed the concern that Federal funds might shift from extramural support to internal Federal laboratory programs. Last year's analysis suggested that this would not be the case, and the most recent NSF data and Battelle's 1984 projections confirm this conclusion. The shares of Federal R&D funding which have been and probably will be performed in Federal laboratories are:

1978	28.7 percent
1979	27.8 percent
1980	26.1 percent
1981	25.9 percent
1982	25.3 percent
1983	24.6 percent
1984	24.1 percent

Greater effort is now being made to "sell" the capabilities of the Federal laboratories as resources available to both the Federal and non-Federal markets. There are, however, conflicts among the various factors that may influence the ultimate outcome of this effort. While Federal regulations permit considerable involvement by Federal laboratories in response to external needs, there also are several real and perceived restrictions. Whether the Federal laboratories will be more heavily involved in R&D performance as a result of actions taken in response to PL 96-480, is yet to be seen. As of this writing, there is little evidence that, taken as a whole, the Federal laboratories are heavily involved in "external" activities. To the extent that they are, there are no reliable statistics which would support any conclusions regarding the support (on a reimbursable basis) or performance of R&D outside the laboratories specific missions.

Last year's analysis pointed to a potential shift of Federal funding from colleges and universities to other nonprofit performers. As of this writing, the shift is not continuing; in fact, it is expected that increases in Federal support to colleges and universities will be slightly greater than the increases to other nonprofit performers.

The Role of Industry

NSF data indicate that industrial support has been greater than Federal support since 1980 and Battelle projects industrial support of R&D to be greater than that from the government in 1984. As has been the case in all previous years, industry will be by far the predominant R&D performer.

During 1983, the NSF has estimated that industry will

provide 51.2 percent of total funding and perform 74.3 percent of all R&D work (see Table 2). Battelle's forecast for 1984 changes these shares almost imperceptibly to 51.8 and 75.2 percent, respectively.

The NSF data base indicates that industry also has been the fastest growing sector. Table 3 compares sectoral growth rates for the nine-year interval 1974–83. In connection with this table, attention is called to two relationships. First, every sector tends to grow somewhat slower as a performer than as a source of funds.* And second, in the case of the government, the fact that this differential exists also indicates a lack of support for the thesis that Federally funded R&D is being transferred to Federal laboratories.

TABLE 3. SECTORAL GROWTH RATES IN FUNDING AND PERFORMING R&D, 1974-83

Sector	1974 = 100.0%	
	Source	Performer
Total United States	263.2	263.2
Federal Government	235.2	198.5
Industry	297.7	280.7
Colleges & Universities	238.6	257.2
Other Nonprofit	212.4	212.2

Source: Derived from Table 1.

Battelle projects considerable differences among the 1983–84 sectoral growth rates. Total R&D expenditures are expected to grow by 8.9 percent; industrial funding and performance are both expected to increase by 10.3 percent, respectively. These represent the highest growth rates among the funding and performing sectors.

Industrial funding is expected to rise from an NSF estimated level of $44,285 million in 1983 to $48,838 million in 1984. Industrial performance will rise from $64,250 million to $70,852 million. As will be seen later, this total performance implies a definite increase in *real* industrial R&D activity (4.7 percent).

Industrial research, as it applies to the accomplishment of industrial and governmental objectives, is both a means to an end and an end in itself. While the continuing profit motive in a competitive marketplace spurs R&D for individual industry's benefit, so also does the industrial system provide a mechanism for the execution of programs of high national priority. In view of: (a) the continuing emphasis on innovation and "reindustrialization", and (b) recent tax incentives for industrial R&D, Battelle's 1984 forecast continues a new area of analysis, namely, the comparative Federal and industrial funding of R&D in major groups of industries.

Using data derived both from NSF sources and from interpolation or extrapolation of the McGraw-Hill surveys, we have estimated the degrees to which industrial and Federal funds will support industry R&D (see Table 4).

This distribution between Federal and industrial funds is, unfortunately, somewhat misleading for it does not address the more critical question of support of R&D among different lines of business. With R&D expenditures grouped according to major SIC classifications, it is not possible to distinguish, for example, electronics research performed by a well-known electronics company from that performed by a subsidiary of a major company whose principal product line (and SIC classification) falls into an entirely different category.

With reference to Tables 2 and 4, the performance of R&D by industry will be financed either by the Federal government or by industry itself. Industrially funded work will mostly be done by industry either internally or contracted to other industry, although a very small amount (less than 2 percent) will be done extramurally by universities and other nonprofit institutions. The nonmanufacturing industries do relatively little R&D and, as noted in Table 4, support for this activity is divided almost equally between Federal and industrial funding. In contrast, R&D is much more heavily self-funded by (and in) the manufacturing industries where, on the average, about 32 percent of the total performance is supported by Federal funds.

The leading industry in the nation for R&D will be the aerospace industry, projected to do almost $16 billion, with almost three-fourths of its funds from Federal sources. In second place will be the electrical machinery and communications industry, projected to spend almost $14.5 billion, of which 40 percent is Federally funded. Since 1980, these two major sectors have dominated and interchanged between first and second place and are expected to dominate in the foreseeable future. Further appropriations for defense systems, as well as anticipated growth in the computers and communications industries, are expected to continue the dominance of these two broad industrial classes.

Aside from aerospace, where Federal support of R&D is dominant, there are no industry groups in which more than half of the R&D performance is expected to be

*Although this appears to be a mathematical anomaly, it results from substantial differences in the two weighing patterns.

supported by Federal grants and contracts. In addition to electrical machinery and communication (39 percent Federal) and rubber products (28.9 percent), no other industries receive as much as 16 percent of their funding from Federal sources.

Finally, we call attention to the fact that the total industry fundings shown in the third column of Table 4 make no distinction between R&D performed in-house or that contracted out to academia, to nonprofit organizations, or to other industrial firms.

Factors Affecting Future Industrial Support

The significant increase expected in industrial support of R&D is linked to three factors. First, the general economic climate appears to be improving and industry is responding to new opportunities foreseen in both the short- and longer-range futures. As greater emphasis is being placed on industrial productivity, revitalization, the growth of the so-called "information society", and the expansion of both consumer and industrial markets, it is anticipated that sales and profits (both early indicators of R&D fund availability) will be increasing in the near term.

Second, there has been a relaxation of (selected real and perceived) barriers to cooperative research programs, thus prompting major multiply-supported research programs at universities, and the creation of the first of what may turn out to be dedicated research centers. The general concept is, of course, not new—multiclient ("group") projects have been performed at Battelle for more than 40 years. But new impetus has been given to the concept through the encouragement of the Federal government, and the magnitude of these dedicated undertakings is expected to be significantly greater than that associated with classical multisponsored programs.

Third, it appears that a portion of the increased R&D expenditures by industry may be attributed to the additional tax incentives for R&D enacted in the early days of the present Administration. Inasmuch as R&D planning by

TABLE 4. ESTIMATED SOURCES OF FUNDS FOR R&D BY BROAD INDUSTRIAL CLASSES, 1984

(Millions of Current Dollars)

Industry Class	Federal Funds	Industry Funds	Total Funds	% Federal
Aerospace	$11,554	$ 4,305	$15,859	72.85
Electrical Machinery and Communications	5,686	8,780	14,466	39.31
Machinery	1,230	9,071	10,301	13.56
Chemicals	733	7,484	8,217	8.92
Autos, Trucks & Parts, & Other Transportation Equipment	920	5,320	6,240	14.74
Professional & Scientific Instruments	922	4,862	5,784	15.94
Petroleum Products	281	2,600	2,881	9.75
Food & Beverage	0	1,024	1,024	0.00
Rubber Products	270	666	936	28.85
Paper	0	690	690	0.00
Iron & Steel	15	607	622	2.41
Stone, Clay, & Glass	40	545	585	6.84
Fabricated Metals & Ordnance	56	510	566	9.89
Nonferrous Metals	31	313	344	9.01
Textiles	0	107	107	0.00
Other Manufacturing	43	1,058	1,101	3.91
Total Manufacturing	21,781	46,712	68,493	31.80
Nonmanufacturing	1,020	1,339	2,359	43.24
TOTAL	22,801	48,051	70,852	32.18

industry usually leads expenditures by one to three years, at a minimum, it was expected that the tax incentives would not have a major impact until 1983 and beyond, as noted in Battelle's 1981 forecast. It appears that the earlier prognoses are now correct.

There remains one significant *caveat*. The extent to which the present forecast reflects an accurate picture of 1984 industrial funding will depend upon a continued growth of the economy. While industry appears to have recovered from the short-term profit-making attitude which recently characterized much business decision making, a return to the "R&D as a dispensable luxury" posture could result from significant reversals in the economy.

A final note regarding industrial support of R&D should be mentioned here. Over the past few years, a slightly different mode of cooperative R&D funding has emerged: that of a "syndication" of venture capital spending which mitigates the risks associated with the reduction of research to commercialization. In many respects, this form of funding is not generically different from the cooperative support by industry which was discussed above. There are, however, two distinctions. First, the efforts are, at this time, devoted more toward development and commercialization than to basic and applied research. Second, the supporting participants are more often smaller investors, rather than major corporations.

As of this time, there are no reliable data that indicate the level of support by this subcategory of industrial funding. If this mechanism were to grow significantly, it may be necessary to include greater consideration of such funding in future issues of the Battelle forecast.

The Role of Academic and Other Nonprofit Institutions

Nonprofit institutions—colleges, universities, and other types—both fund their own research and conduct research funded by Federal agencies and or industrial firms. It is generally conceded that a significant portion of all basic research is conducted in this sector, as well as some of the longer maturing applied research.

In 1960, the academic and other nonprofit institutions financed from their own resources (including endowments and direct state and local funds) approximately 2 percent of all R&D (see Table 1), while actually performing over 9 percent of the total. For 1984, Battelle forecasts (see Table 2) that these same nonprofits will provide 2.9 percent of all funding and will perform 13.9 percent of the total.

These percentages are slightly lower than the corresponding ratios for the 1983 NSF estimates. Both academic and other nonprofit performers will experience increases in funding, but barely in line with the projected inflation rate.

The growth in nonprofit R&D performance has been accompanied by minor shifting within the nonprofit sector. In 1960, the academic community (universities and colleges) accounted for 55.4 percent of total nonprofit funding and performed 78.1 percent of the nonprofit total. For 1984, Battelle forecasts 63.3 percent and 80.1 percent, respectively.

Attention is called to the part played in these developments by the nonacademic nonprofit organizations. There are two distinct groups of these "other" nonprofit organizations, the *foundations* which exist primarily for charitable purposes and the *nonprofit research centers* which may or may not perform under contract. The first group funds a great deal of research, primarily through the mechanism of grants; and these grants go both to members of the academic community and to other nonprofit centers. The second group acts in three ways: a member may perform as a foundation; it may fund its own research performance; and or it may perform under contracts (with government, industry, or other nonprofits).

From 1965 to 1980 other nonprofit performance has fluctuated slightly between 3.3 and 3.7 percent of total R&D. Since then, this sector has declined to less than 3 percent. For 1984, Battelle estimates that the other nonprofit sector will comprise 2.76 percent of total R&D performance. Furthermore, we estimate that 49.5 percent of other nonprofit funding will go to colleges and universities, with the remaining 50.5 percent being spent by the other nonprofit sector itself. This division of support is more even than that estimated by NSF for calendar year 1983.

The total R&D performance in the other nonprofit sector is not increasing as rapidly as in other performing sectors. However, a word of clarification is appropriate. As noted above, this sector is quite diverse in the character of the constituent organizations. As performers of R&D, the establishments within this sector range from institutions such as Battelle (engaged in a broad spectrum of programs in the classic science and technology fields as well as in economics and other social sciences) to small nonprofit firms that act as delivery mechanisms and research arms for Federal, state, or local government agencies, especially for social programs.

The activities of these latter types of organizations have been significantly curtailed in recent years. Hence, it is not unexpected that the aggregate of nonprofit performers should display smaller-than-average growth rates, or, in fact, real declines in comparison with other performing sectors.

Finally at this point, attention is called to the variety of forms taken by industrial support for academic R&D. In addition to contracts or grants to support research on industrial problems (this is the "industry funding of colleges and universities" shown in Table 2) there is a new form of support, not yet reported in detail by the NSF, that must be noted. These industry–university arrangements take a form that more nearly resembles a "directed endowment" rather than either a specific research contract or a general gift. The large multiyear programmatic grants are then accounted for in terms of college and university self-funding.

Although major endowments of universities or individual departments may accomplish objectives that are important both to academia and to industry, not all such partnerships have been completely welcomed. On the positive side, these major programs may foster advanced university research and industrial access to faculty and graduate students. Furthermore, they provide a mechanism for promoting further graduate research and education—countering a trend that has been disturbing to both the universities and industry.

On the other hand, there has been some reluctance toward the development and concentration of university research programs in areas closely tied to potential commercial ventures. The academic community may be willing to develop patents and possible commercial spinoff industry, but there is certainly less enthusiasm for creating situations in which external forces might dictate department policy. Industrial reluctance for these arrangements derives from the difficulty of maintaining proprietary claims and confidentiality with respect to the findings of industrially sponsored research.

The Cost of R&D Inputs

From an economic point of view, inflation can be defined as a general rise in the price of goods and services that is not offset by corresponding increases in quality. If the prices of everything tend to rise together, slowly, and in the same proportions—and if individual incomes also rise in those same proportions—the relations between money and goods services change, but in a fashion which is detrimental mainly to the holders of such fixed-dollar obligations as life insurance. On the other hand, when the prices of things bought with income rise faster than the incomes, structural imbalances occur which may be quite painful to particular sectors of the economy.

Goods Versus Services

Most considerations of prices tend to take place within the context of goods' prices, i.e., the prices of tangible things. The very tangibility of goods makes it possible both to measure the quantity of their output and to estimate, within reasonable limits, changes in their quality. Thus, with respect to goods, there usually is agreement as to whether or not costs are rising faster than output, or prices faster than quality—that is to say, we tend to have general agreement that inflation is or is not occurring in the goods-related economy.

Services, on the other hand, are intangible. Therefore we usually have greater difficulty achieving agreement that, in terms of any meaningful measure, the quantity or quality of service output is rising or falling. As a result, our only measure of many types of service output is the total amount of money that we pay for them—and that is a function of price and quantity, with no account taken of quality.

R&D, by definition a part of the "knowledge industry", is primarily a service activity, despite the fact that much of it ultimately becomes embodied in products. For this reason, we have no agreement as to what can be termed a "unit" of R&D output; and we, therefore, cannot ascertain whether or not the "price" of R&D *output* is rising or falling. We can price R&D *inputs*, however, and for that reason most discussions of the cost of R&D tend to be couched in those terms. Battelle has not yet given up hope of achieving a measure of R&D output, and from time to time has undertaken investigations which may lead to the quantification of at least some kinds of R&D output. Nevertheless, such a measure is not now available and the discussion which follows must be in terms of input costs.

The "Cost of R&D Input" Index

In the absence of a measure of R&D output costs, many organizations, including the NSF, use the GNP deflator (from the national income and product accounts) as an indicator of changes in R&D costs. This index responds to the costs of both goods and services. R&D costs are made up primarily of service costs, however, for which reason Battelle researchers feel that the GNP deflators probably have misstated recent rates of inflation with respect to R&D.

Several attempts have been made in the recent past to determine the input mixes of typical R&D activities and to price each input, thereby generating standard weighted price indexes for R&D. To date, this approach has not been very productive, although such efforts continue and may eventually achieve success.

A pioneering effort at more directly measuring trends and fluctuations in the cost of R&D was made by Helen Milton* beginning in 1966. Using information supplied by representative R&D performers Milton compiled data on the total dollar cost of R&D per technical (professional) man-year.** Her series of cost indexes ended with 1970, using 1950 as the base year. Between 1970 and 1979 Battelle extended the Milton Index series by means of annual estimates. Finally a new series of R&D cost indexes was introduced in the 1980 Battelle Forecast and Analysis. This new series, while conceptually similar to the Milton Series, is based upon a different body of data and does not show precisely the same year-to-year changes as the Milton Series and our earlier extensions thereof.

The Battelle Cost of Research Index, displayed in Table 5, is based upon two series regularly published by the NSF: (a) the R&D performance figures, by Sectors, that have already been discussed in connection with the Source Performer Matrix (Table 2); and (b) estimates of the full-time equivalent numbers of R&D scientists and engineers employed by each performing sector. The ratio of costs to scientists engineers for each sector provides the basis for the sectoral subseries, which are then weighted and combined into the all-sector average.***

*See Helen S. Milton: "Cost of Research Index, 1920-1970" *Operations Research*, 20, 1, 18 (1972).

**Milton said on p. 1: "The 'technical man' is the professional scientist or engineer, plus his support."

***As noted, in the text, the Battelle Cost of Research Index is derived from both NSF data and our own projections. Variations in the

TABLE 5. BATTELLE COST OF RESEARCH INDEX* BY PERFORMING SECTORS, CALENDAR YEARS 1960-84 (1972 = 100.00)

		Performing Sectors			
Year	Total U.S.	Federal Government	Industry	Colleges and Universities	Other Nonprofits
1960	59.17	49.22	62.57	46.51	72.56
1961	60.68	51.45	63.28	52.65	74.47
1962	62.90	54.82	64.64	59.26	77.12
1963	67.12	56.59	69.28	65.79	76.19
1964	71.76	67.49	72.36	73.35	75.08
1965	73.39	70.22	73.70	75.37	76.29
1966	77.10	70.59	78.17	78.79	80.70
1967	78.54	71.65	79.51	81.47	82.12
1968	81.34	72.09	82.58	85.43	86.30
1969	83.89	71.96	85.94	85.35	93.97
1970	86.66	84.79	86.06	89.66	98.94
1971	90.85	89.88	90.11	94.82	97.59
1972	100.00	100.00	100.00	100.00	100.00
1973	108.80	105.38	109.89	108.29	104.71
1974	116.15	109.37	118.19	112.34	120.43
1975	120.63	118.48	120.34	123.17	127.04
1976	130.12	128.48	129.96	131.93	134.08
1977	137.93	136.70	137.16	142.49	142.64
1978	148.34	149.91	145.54	161.53	153.15
1979	160.57	162.09	156.54	181.76	166.04
1980	173.16	166.16	169.99	198.66	181.11
1981	190.99	185.56	187.74	217.08	194.22
1982	201.77	196.64	199.83	219.87	203.07
1983	213.14	207.27	211.83	227.96	215.22
1984	223.85	218.32	223.04	236.28	221.02

*Costs of performing R&D per scientist, engineer (full time equivalence).

Source: Estimated by Battelle from NSF and Battelle data.

As derived from Table 5, Battelle's best estimates of recent increases in the total index are 10.3 percent for 1980-81, 5.6 percent for 1981-82, and 5.6 percent for 1982-83. We expect the cost of R&D to increase by about 5.0 percent between the estimated 1983 level (213.14) and the forecast level for 1984 (223.85) with the estimates stated in terms of the 1972 base.

Sector Comparisons of R&D Costs

During the interval 1972-84 costs of all R&D, as an average, are estimated to have risen by 123.85 percent. Increases in the individual performing sectors are expected to be: Federal government, 118.32 percent; industry 123.04 percent; colleges and universities, 136.28 percent; and other nonprofit, 121.02 percent. As noted, the 1983-84 cost increase for all R&D is estimated to be 5.02 percent. By sectors, the increases are estimated as Federal, 5.33 percent; industry, 5.29 percent; colleges and universities, 3.65 percent; and other nonprofits, 2.69 percent.

Trends in Real R&D Effort, by Sectors

If we take total expenditures and sector performance figures from Tables 1 and 2 and deflate them to constant 1972 dollars with the corresponding index numbers from Table 5, we can make parallel comparisons for each of the four performing sectors. These are shown in Table 6 and graphed in Figures 3 and 4.

In current (undeflated) dollars, total U.S. R&D expenditures have risen in every year of the period, even though the rate of increase fell sharply between 1969 and 1971. But the deflated (real effort) series before 1978 reached its peak in 1969, declined between 1969 and 1973, and moved generally sideways until 1977, when it exceeded $30 billion for the first time in 7 years. We expect real R&D effort in 1984 to increase by 3.7 percent over 1983 and to reach a level that is 37.8 percent above its 1969 peak.

historical cost index, as reported in these Forecasts, are generally attributable to changes in the NSF data, which are continuously adjusted. Note, for example, that the *Patterns* report for 1982 contains adjustments in data dating back to 1970, and the *Highlights* report, noted earlier, contains adjustments in data dating back to 1977.

TABLE 6. CURRENT AND CONSTANT DOLLAR (1972 = 100) R&D EXPENDITURES IN THE U.S., 1960-1984, BY PERFORMERS

(All Amounts in Millions of Dollars)

	Total U.S.		Federal Government		Industry		Colleges and Universities		Other Nonprofits	
Year	Current	Constant	Current	Constant	Current	Constant	Current	Constant	Current	Constant
1960	13.523	22.854	1.726	3.507	10.509	16.795	1.006	2.163	282	389
1961	14.316	23.592	1.874	3.642	10.908	17.237	1.173	2.228	361	485
1962	15.394	24.474	2.098	3.827	11.464	17.734	1.374	2.319	458	594
1963	17.059	25.415	2.279	4.027	12.630	18.232	1.611	2.449	539	707
1964	18.854	26.274	2.838	4.205	13.512	18.674	1.904	2.596	600	799
1965	20.044	27.312	3.093	4.405	14.185	19.248	2.103	2.790	663	869
1966	21.846	28.335	3.220	4.561	15.548	19.889	2.345	2.976	733	908
1967	23.146	29.470	3.396	4.740	16.385	20.607	2.594	3.184	771	939
1968	24.605	30.251	3.494	4.847	17.429	21.104	2.868	3.357	814	943
1969	25.631	30.554	3.503	4.868	18.308	21.303	2.950	3.457	870	926
1970	26.134	30.157	4.079	4.811	18.067	20.994	3.072	3.426	916	926
1971	26.676	29.361	4.228	4.704	18.320	20.331	3.216	3.392	912	935
1972	28.477	28.477	4.590	4.590	19.552	19.552	3.383	3.383	952	952
1973	30.718	28.234	4.762	4.519	21.249	19.337	3.701	3.418	1.006	961
1974	32.864	28.293	4.911	4.490	22.887	19.364	3.888	3.461	1.178	978
1975	35.213	29.191	5.354	4.519	24.187	20.099	4.396	3.569	1.276	1.004
1976	39.016	29.984	5.769	4.490	26.997	20.773	4.874	3.694	1.376	1.026
1977	42.829	31.051	6.060	4.433	29.825	21.745	5.449	3.824	1.495	1.048
1978	48.184	32.482	6.870	4.583	33.304	22.683	6.338	3.924	1.672	1.092
1979	54.972	34.235	7.463	4.604	38.226	24.419	7.289	4.010	1.994	1.201
1980	62.734	36.228	7.769	4.676	44.505	26.182	8.285	4.170	2.175	1.201
1981	72.118	37.760	8.729	4.704	51.830	27.607	9.269	4.270	2.290	1.179
1982	79.000	39.154	9.250	4.704	57.850	28.950	9.550	4.343	2.350	1.157
1983	86.500	40.583	9.750	4.704	64.250	30.331	10.000	4.387	2.500	1.162
1984	94.236	42.098	10.270	4.704	70.852	31.767	10.508	4.447	2.606	1.179

Source: Current dollar figures from Tables 1 and 2, deflated in terms of Battelle R&D Cost Index of Table 5.

When we shift our attention to the performing sectors, we find that the recent upward drift of real R&D activity results from the behavior of the private sectors. The downturn or flat behavior in real expenditures that began after 1968–69 is clearly reflected by every sector. However, deviations in sector behavior emerged later, especially since about 1975. In government, the real performance series has recovered only slowly from its 1974 minimum and has not yet equalled its 1969 peak.

In the private sectors, industry reached its real low in 1973 and has since risen by 64 percent to its highest recorded value. The academic community reached its low in 1972. Since then, its real performance has risen by 31 percent and now stands well above the 1968 value. Other nonprofit institutions' real performance declined from 1968 through 1970. Since that time it has risen by 27 percent to a level of 25 percent above the 1968 peak.

Finally, we turn to the data of Table 6 and the curves of Figures 3 and 4 to see the dramatic differences in the R&D trends among the four performing sectors. Since the lull of the early 1970s, industrial performance, funded by both government and industry, has been largely responsible

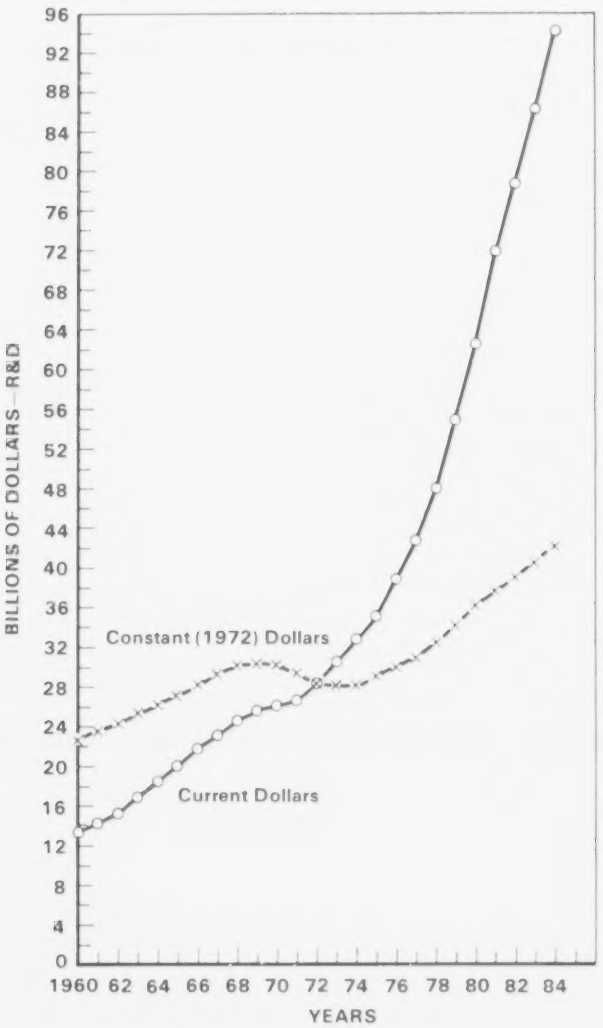


FIGURE 3. TOTAL R&D EXPENDITURES, 1960-84, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1972 = 100%)

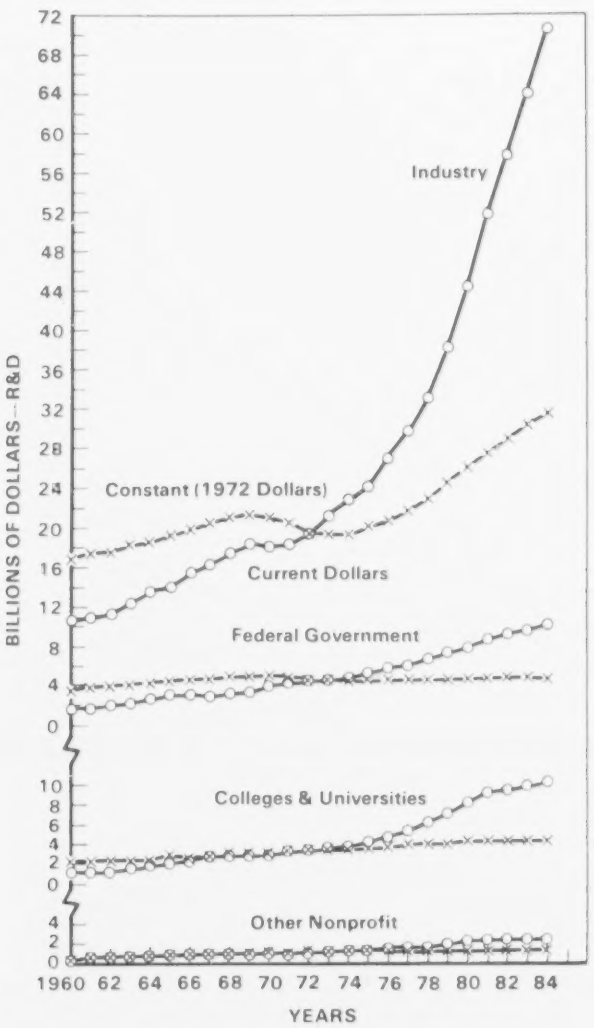


FIGURE 4. R&D EXPENDITURES BY SECTORS, 1960-84, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1972 = 100%)

for the real growth within the R&D enterprise. Using the same performance deflators as applied to the sources of funds, it is seen that over the past decade, industrial support of R&D has increased at an average compounded rate of 5.20 percent per year, while Federal support has increased at 2.18 percent per year on average.

The behavior exhibited in Figures 3 and 4 suggests that the real growth in R&D — and the economic development and expansion that result from it — has come from the applied research supported and performed by private industry. However, one cannot overlook the fact that such applied research and development must rest on, and evolve from, the basic research foundation — an activity that is primarily supported by the Federal government (almost 70 percent).

Over the past few years, Federal support has tended to shift toward more "development" and less basic and applied "research". If such trends continue, the long-range consequences may pose significant problems in terms of the science base upon which economic vitality grows. Such problems may, in part, be mitigated by a continuation of the recent resurgence of basic research support by industry (the "directed endowments" referred to earlier). However, the volatility of those indicators (sales, profits, cash flow) which influence industrial R&D budgets precludes a stability for long-term planning.

Thus, the Federal government, in any attempt to maintain the vitality of our technology-based and technology-influenced economy, should continually reexamine its policies relative to (a) the support of R&D, (b) the roles of the private and public sectors, (c) the factors which enhance or impede the progress of science and technology, and (d) the commitment to science education at all levels.

A Look Toward 1985

While former issues of the Battelle *Forecast and Analysis* have been confined to consideration of just the forthcoming year, well-established commitments by both the Federal government and industry permit a preliminary longer look at the R&D forecast. Judging from recent trends in government spending, long-term budget authorities, and the existing overall business climate, it is estimated that 1985 sources for R&D will be:

Federal government	$ 46,060 million
Private industry	52,430 million
Colleges & Universities	1,790 million
Other Nonprofit Organizations	1,000 million
TOTAL	$101,280 million

In addition, it is estimated that 1985 expenditures of R&D will be distributed among the four performing sectors as follows:

Federal government	$10,750 million
Private industry	77,150 million
Colleges & Universities	10,760 million
Other Nonprofit Organizations	2,620 million

The overall 7.5 percent increase in funding (expressed in 1984 constant dollars) is dominated by a continuing significant growth in the support by government and industry, with lesser growth rates in the other funding sources. All else being equal (which is seldom the case), the present long-term commitment to defense systems will lie at the base of expanded Federal R&D programs.

There is little — or perhaps much — that could be speculated regarding nondefense R&D in 1985, depending upon the direction of the Presidential campaign and its outcome. One can argue on both sides relative to the fate of nondefense R&D if the present Administration were to continue.

On the other hand, in the event that political change occurs in the Administration, it would be expected that significant efforts would be made to force reductions in defense expenditures and the associated R&D (the amount and targeting of such recisions being dependent upon the actual successful candidate). However, the results of such actions in 1985 under these conditions would be significantly different from those which occurred in the 1981 cutbacks.

Industrial support for R&D is also expected to grow substantially, although at a slightly smaller real growth rate than that represented by Federal government support. A continued Federal effort to relax restrictions and to encourage economic expansion will contribute to this expansion of industrially sponsored research. However, this may be partially counterbalanced by a slowing of the growth of R&D spurred by the special tax credits that will have come to fruition in 1984. That is to say, those firms which would be significantly affected by the tax credits will already have made their commitment to the concept of additional R&D.

As performers of R&D, industry is expected to be the major growth sector, with all others showing small real increases or merely breaking even. This skewed expansion could have both positive and negative consequences. On the one hand, a proportionate increase in performance by industry can lead to a closer relationship between R&D (especially applied research and product-oriented development) and the market. Such close ties are thought to be one

of the contributing factors to the economic growth of other countries.

On the other hand, however, the concentration of R&D performance in industry must be accompanied by a concomitant decrease, or smaller increase, in the performance by colleges, universities, and other nonprofit organizations. One major consequence of this continuing shift would be a decrease in the amount of the basic research that has provided the foundation of past and present technical and economic strength.

As plans are being made for 1985 and beyond, R&D planners and managers in all sectors should undertake a more careful and integrated examination of the implications of R&D distribution, especially in the context of other policy objectives.

TECHNICAL APPENDIX

NSF DEFINITIONS OF RESEARCH AND DEVELOPMENT

Many activities, from one viewpoint or another, may be termed "Research and Development". The National Science Foundation (NSF) has, since its inception, been concerned with both the definition and the measurement of R&D. We probably can do no better than again quote the most recent definitions that the NSF has evolved. By these definitions, we can say:

"*Research and development* . . . consist of basic and applied research in the sciences (including medical sciences) and in engineering and activities in development . . .

"*Research*, which encompasses both basic and applied, is systematic, intensive study directed toward fuller scientific knowledge of the subject studied.

"*Basic research*. For three of the sectors—federal government, universities and colleges, and other nonprofit institutions—the definition of basic research stresses that it is directed toward increases of knowledge in science with . . . a fuller knowledge of understanding of the subject under study, rather than a practical application thereof. To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to indicate that basic research projects represent . . . original investigations for the advancement of scientific knowledge . . . which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

"*Applied Research*. The following is the core definition in the NSF questionnaire sent to the universities and colleges: '*Applied research* is directed toward practical application of knowledge'. Here again, the definition for the industry survey takes account of the characteristics of industrial organizations it covers '. . . research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes'. By this definition, applied research in industry differs from basic research chiefly in terms of objectives of the reporting company.

"*Development*. The NSF survey concept of development may be summarized as '. . . the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes'."*

*National Science Foundation, *National Patterns of R&D Resources*, 1953-78-79, NSF 78-313, p. 25.

ABOUT BATTELLE-COLUMBUS

Battelle's Columbus Division is the original contract research center of Battelle Memorial Institute, an internationally recognized nonprofit scientific research and development organization with laboratories and offices throughout the world.

Research at Battelle-Columbus encompasses virtually all facets of science and its application, including fundamental research and education. Studies are funded by small and large industrial firms; by municipal, regional, state, and Federal government agencies; and by associations and private groups in the United States and abroad. Research ranges from performing short-term, modest, problem-solving investigations to conducting and managing long-term, multidisciplinary, multimillion-dollar programs.

In conducting research, Battelle provides the sponsor with the physical facilities, equipment, and personnel on a contract basis. More than 2,000 studies in diverse fields are pursued in a typical year. Among the major research areas are energy, environmental quality, resource management, applied and technical economics, social and behavioral sciences, health sciences, engineering and manufacturing technology, materials sciences, transportation, national security, and electronics.

Battelle-Columbus also has extensive research facilities at nearby West Jefferson, Ohio, where nuclear, life sciences, and large-scale, pilot-plant studies are conducted. Other components include Battelle's New England Marine Research Laboratory, Duxbury, Massachusetts, a pioneer in marine biology and ecology studies; the Florida Marine Research Facility, near Daytona Beach, Florida; and Battelle's Petroleum Technology Center, Houston, Texas.

The staff numbers more than 3,000 scientists, engineers, and supporting specialists whose training and expertise embrace the physical, life, social, and behavioral sciences. Research volume at Battelle-Columbus is more than $140 million a year.

Battelle Memorial Institute, headquartered in Columbus, Ohio, was established by the Will of Gordon Battelle. The Institute has as its broad objective the benefit of mankind by the advancement and utilization of science through a broad range of research, development, and demonstration programs, as well as educational, and invention and technology development activities. In helping to meet the challenges of today, its goal is to advance knowledge through research and other creative scientific activities and to apply that knowledge to improve the quality of life. In addition to conducting sponsored research for others, Battelle maintains its own research, development, educational, and invention-development programs.

Research operations at Battelle began in 1929 with a staff of 30 people. Today, the staff numbers more than 7,100 worldwide and research volume is in excess of $426 million annually. Battelle operates major research facilities in Columbus, Ohio; Richland, Washington; Geneva, Switzerland; and Frankfurt, Germany. Additionally, it has offices and correspondents in various cities in the United States, Europe, Latin America, Australia, and the Far East.

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